Chapter 7
Lubricant Additives

7-1. General

Oil quality is established by the refining processes and additives are most effective if the oil is well refined. Although the overall performance of an oil can be improved by introducing additives, a poor quality oil cannot be converted into a premium quality oil by introducing additives. Furthermore, there are limits to the amount of additives that can be introduced to improve performance. Beyond these limits, the benefits are minimal or may provide no gains in performance. They also may increase the cost of lubricants and, in some cases, may even be harmful. An additive may function in any of the following three ways:

- Protecting lubricated surfaces. Extreme pressure (EP) additives and rust inhibitors are included in this category. These additives coat the lubricated surfaces and prevent wear or rust.

- Improving performance. Viscosity index improvers and antifoaming agents are examples. They make the oil perform in a desired manner for specific applications.

- Protecting the lubricant itself. Antioxidants reduce the tendency of oil to oxidize and form sludge and acids.

The most common additives are listed in Table 7-1, and they are discussed individually in the following paragraphs.

7-2. Surface Additives

The primary purpose of surface additives is to protect lubricated surfaces. Extreme pressure additives, rust and corrosion inhibitors, tackiness agents, antiwear additives, and oiliness additives are included in this category. These additives coat the lubricated surfaces to prevent wear or rust.

a. Rust inhibitors. Rust inhibitors are added to most industrial lubricants to minimize rusting of metal parts, especially during shipment, storage, and equipment shutdown. Although oil and water do not mix very well, water will emulsify--especially if the oil contains polar compounds that may develop as the oil ages. In some instances the water will remain either suspended by agitation or will rest beneath the oil on machine surfaces when agitation is absent. Rust inhibitors form a surface film that prevents water from making contact with metal parts. This is accomplished by making the oil adhere better or by emulsifying the water if it is in a low concentration.

b. Corrosion inhibitors. Corrosion inhibitors suppress oxidation and prevent formation of acids. These inhibitors form a protective film on metal surfaces and are used primarily in internal combustion engines to protect alloy bearings and other metals from corrosion.

c. Extreme pressure (EP) agents. Extreme pressure agents react with the metal surfaces to form compounds that have a lower shear strength than the metal. The reaction is initiated by increased temperature caused by pressure between asperities on wearing surfaces. The reaction creates a protective coating at the specific points where protection is required. This coating reduces friction, wear, scoring,

Table 7-1
Types of Additives

Main Type	Function and Subtypes
Acid neutralizers	Neutralize contaminating strong acids formed, e.g., by combustion of high sulfur fuels or by decomposition of active EP additives.
Antifoam	Reduce surface foam.
Antioxidants	Reduce oxidation. Various types are: oxidation inhibitors, retarders; anticatalyst metal deactivators, metal passivators.
Antirust	Reduce rusting of ferrous surfaces swept by oil.
Antiwear agents	Reduce wear and prevent scuffing of rubbing surfaces under steady load operating conditions
Corrosion inhibitors	Type (a) reduces corrosion of lead; type (b) reduces corrosion of cuprous metals.
Detergents	Reduce or prevent deposits formed at high temperatures, e.g., in internal combustion engines.
Dispersant	Prevent deposition of sludge by dispersing a finely divided suspension of the insoluble material formed at low temperature.
Emulsifiers	Form emulsions; either water-in-oil or oil-in-water, according to type.
Extreme pressure	Prevent scuffing of rubbing surfaces under severe operating conditions, e.g., heavy shock load, by formation of a mainly inorganic surface film.
Oiliness enhancers	Reduce friction under boundary lubrication conditions; increase load-carrying capacity where limited by temperature rise by formation of mainly organic surface films.
Pour- point depressants	Reduce pour point of paraffinic oils.
Tackiness agents	Reduce loss of oil by gravity, e.g., from vertical sliding surfaces, or by centrifugal force.
Viscosity index improvers	Reduce the decrease in viscosity due to increase of temperature

Reference: Neale, M. J., Lubrication: A Tribology Handbook. Butterworth-Heinemann Ltd., Oxford, England.

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seizure, and galling of wear surfaces. Extreme pressure additives are used in heavy loading or shock loading applications such as turbines, gears, and ball and roller bearings.

d. Tackiness agents. In some cases, oils must adhere to surfaces extremely well. Adding polymers composed of long-chain molecules or aluminum soaps of long-chain fatty acids increases the tackiness or adhesiveness of oils.

e. Antiwear (AW) agents. Additives that cause an oil to resist wear by coating the metal surfaces are called antiwear agents. Molecules of the antiwear compound are polar and attach (adsorb) themselves to metal surfaces or react mildly with the metal. When boundary lubrication conditions (direct contact between metal asperities) occur, such as in starting and stopping of machinery, these molecules resist removal more than ordinary oil molecules. This reduces friction and wear. However, they are effective only up to about 250 °C (480 °F).

f. Detergents and dispersant. Detergents and dispersant are used primarily in internal combustion engines to keep metal surfaces clean by preventing deposition of oxidation products.

g. Compounded oil. A small amount of animal fat or vegetable oil added to a mineral oil will reduce the coefficient of friction without affecting the viscosity. The ability of an oil to provide a lower coefficient of friction at a given viscosity is often called oiliness or lubricity. When fatty oil is added to obtain this quality of oiliness, the lubricant is called a compounded oil. Fatty oil adheres to metal more strongly than mineral oil and provides a protective film. Compounded oils are generally used in worm gears.

7-3. Performance-Enhancing Additives

These additives improve the performance of lubricants. Viscosity index improvers, antifoaming agents, emulsifiers, demulsifiers, and pour-point depressants are examples.

a. Pour-point depressants. An oil's pour point is the temperature at which the oil ceases to flow under the influence of gravity. In cold weather, oil with a high pour point makes machinery startup difficult or impossible. The stiffness of cold oil is due to paraffin waxes that tend to form crystal structures. Pour-point depressants reduce the size and cohesiveness of the crystal structures, resulting in reduced pour point and increased flow at reduced temperatures.

b. Viscosity index (VI) improvers. The viscosity index is an indicator of the change in viscosity as the temperature is changed. The higher the VI, the less the viscosity of an oil changes for a given temperature change. Viscosity index improvers are used to limit the rate of change of viscosity with temperature. These improvers have little effect on oil viscosity at low temperatures. However, when heated, the improvers enable the oil viscosity to increase within the limited range permitted by the type and concentration of the additive. This quality is most apparent in the application of multigrade motor oils.

c. Emulsifiers. In most industrial applications it is undesirable to have emulsified water in the oil. However, soluble oils require emulsifiers to promote rapid mixing of oil and water and to form stable emulsions. Soluble oils are used as lubricants and coolants for cutting, grinding, and drilling applications in machine shops.

d. Demulsifiers. Demulsifiers promote separation of oil and water in lubricants exposed to water.

7-4. Lubricant Protective Additives

Lubricant protective additives are employed to protect the lubricant instead of the equipment. Oxidation inhibitors and foam inhibitors are examples.

a. Oxidation inhibitors. Over time, hydrocarbon molecules will react to incorporate oxygen atoms into their structure This reaction produces acids, sludge, and varnish that foul or damage metal parts. At low temperatures and under minimal exposure to oxygen, this process is very slow. At temperatures above 82 $^\circ$C (180 $^\circ$F) the oxidation rate is doubled for every -7.78 to -6.67 $^\circ$C (18 to 20 $^\circ$F) rise in temperature. Oxidation of hydrocarbons is a very complex chemical process and depends on the nature of the oil. Oxidation inhibitors reduce the quantity of oxygen reacting with oil by forming inactive soluble compounds and by passivating metal-bearing surfaces to retard the oxidation rate. As previously noted, oxidation inhibitors are consumed as the oil ages. Oil condition should be monitored periodically to ensure that essential additives are maintained at safe levels. Oxidation inhibitors are used in most industrial lubricant applications where oil is continuously circulated or contained in a housing.

b. Foam inhibitors. In many applications, air or other gases may become entrained in oil. Unless these gases are released, a foam is produced. Foaming can result in insufficient oil delivery to bearings, causing premature failure. Foam may also interfere with proper operation of equipment such as lubricating pumps and may result in false oil level readings. Under some circumstances foam may overflow from oil reservoirs. Foam inhibitors such as silicone polymers or polyacrylates are added to reduce foaming.

7-5. Precautions

a. Additives alone do not establish oil quality with respect to oxidation resistance, emulsification, pour point, and viscosity index. Lubricant producers do not usually state which compounds are used to enhance the lubricant quality, but only specify the generic function such as antiwear, EP agents, or oxidation inhibitors. Furthermore, producers do not always use the same additive to accomplish the same goal. Consequently, any two brands selected for the same application may not be chemically identical. Users must be aware of these differences and that they may be significant when mixing different products.

(1) Additive depletion. Certain precautions must be observed with regard to lubricant additives. Some additives are consumed during use. As these additives are consumed, lubricant performance for the specific application is reduced and equipment failure may result under continued use. Oil monitoring programs should be implemented to periodically test oils and verify that the essential additives have not been depleted to unacceptable levels.

(2) Product incompatibility. Another important consideration is incompatibility of lubricants. Some oils, such as those used in turbine, hydraulic, motor, and gear applications are naturally acidic. Other oils, such as motor oils and transmission fluids, are alkaline. Acidic and alkaline lubricants are incompatible.

b. When servicing an oil lubricating system, the existing and new oils must be compatible. Oils for similar applications but produced by different manufacturers may be incompatible due to the additives used. When incompatible fluids are mixed, the additives may be consumed due to chemical reaction with one another. The resulting oil mixture may be deficient of essential additives and therefore unsuitable for the intended application. When fresh supplies of the oil in use are not available, the lubricant manufacturer should be consulted for recommendation of a compatible oil. Whenever oil is added to a system, the oil and equipment should be checked frequently to ensure that there are no adverse reactions between the new and existing oil. Specific checks should include bearing temperatures and signs of foaming, rust, or corrosion.